ANNEXURES

Annexure-I
(as referred to in Para 2.2)
Consultants/ in – house Reports cited in the Audit Report

Sl. No.	Name of the consultant	Year	Category
1	RGL report on Water quality monitoring parameters (February 1984)	1984	In-house
2	Bombay High review committee by Das Gupta	1990	In-house committee
3	Caproco International Ltd. Report on Corrosion problem and recommendation remedial measures	1998	International
4	Mumbai High and Neelam Heera Water Injection projects by Ganesh Thakur (2007)	2007	International
5	Evaluation of the Mumbai High field by William Cobb & Associates	2009	International
6	Project memorandum of M/s. GCA regarding Achieving 40% recovery in Mumbai High field	2009	International
7	IRS report on Injection Water quality and injectivity assessment of Injectors of Mumbai High	2011	In-house institute
8	Failure analysis of Water Injection pipeline by Institute of Engineering and Ocean Technology	2012	In-house institute
9	Report on facility cost optimisation and Water Injection improvements in Mumbai High	2012	In-house committee
10	Peer review of the Field Development Plan for Mumbai High South Ph-III by M/s. Bayphase	2014	International
11	Committee report on Pre-mature failure of water injection pipelines	2014	In-house committee
12	Review of tubing metallurgy for water injection wells Institute of Oil & Gas Production Technology	2016	In-house institute
13	Task force committee report on Augmentation and Redistribution of Water Injection in Mumbai High	2018	In-house committee
14	Performance analysis of recently side-tracked wells Institute of Oil and Gas Production Technology (IOGPT)	2018	In-house institute
15	ONGC Energy Strategy -2040 by The Boston Consultancy Group	2018	International
16	ONGC offshore five fields peer review by Gaffney, Cline & Associates (Mumbai High)	2019	International
17	ONGC offshore five fields peer review by Gaffney, Cline & Associates (Heera)	2019	International
18	ONGC offshore five fields peer review by Beicep Franlab (Neelam)	2019	International

Annexure-II (as referred to in Para 3.3)

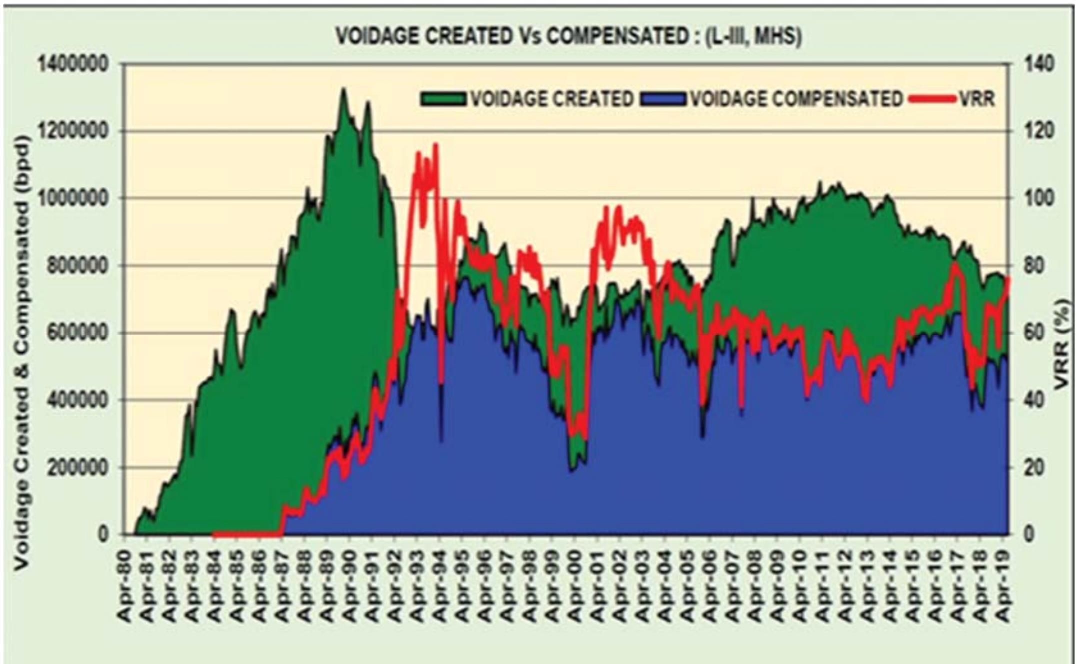
Plan v/s Actual Water Injection in Mumbai High, Neelam and Heera fields										
Year	**Mumbai High South**					**Mumbai High North**				
	Requirement as per redevelopment plan-bwpd	Water injection build-up plan-bwpd	Actual water injection -bwpd	Shortfall actual WI-w.r.t. redevelopment plan (%)	Shortfall in WI-w.r.t. build-up plan (%)	Requirement as per redevelopment plan-bwpd	Water injection build-up plan –bwpd	Actual water injection -bwpd	Shortfall Actual WI-w.r.t. redevelopment plan (%)	Shortfall Actual WI-w.r.t. build-up plan (%)
2014-15	623728	604000	534689	14.28	11.48	489843	456900	394383	19.49	13.68
2015-16	782253	652300	582880	25.49	10.64	542895	427800	367240	32.36	14.16
2016-17	786461	621900	613800	21.95	1.30	562031	375700	376700	32.98	-0.27
2017-18	784145	622300	519200	33.79	16.57	559416	382360	403000	27.96	-5.40
2018-19	793774	577300	470402	40.44	18.10	548022	407300	389755	29.31	4.89
			Average	**27.19**	**11.62**				**28.42**	**5.41**
Year	**Heera**					**Neelam**				
	Requirement as per redevelopment plan-bwpd	Water injection build-up plan-bwpd	Actual water injection-bwpd	Shortfall Actual WI-w.r.t. redevelopment plan (%)	Shortfall in WI-w.r.t. build-up plan (%)	Requirement as per redevelopment plan-bwpd	Water injection build-up plan – bwpd	Actual water injection-bwpd	Shortfall Actual WI-w.r.t. redevelopment plan (%)	Shortfall actual WI-w.r.t. build-up plan (%)
2014-15	202099	128550	119667	40.79	6.91	98225	61811	58319	40.63	5.65
2015-16	205459	89542	86657	57.82	3.22	74625	62508	58288	21.89	6.75
2016-17	209234	142292	108872	47.97	23.49	88130	96963	65344	25.85	32.61
2017-18	174848	165500	121876	30.30	26.36	120813	79800	63439	47.49	20.50
2018-19	184393	172125	115462	37.38	32.92	142366	113808	68046	52.20	40.21
			Average	**42.85**	**18.58**				**37.61**	**21.14**
Bwpd - Barrel of water per day										

Annexure III
(as referred to in Para 3.4)
Plan versus execution of annual plan inputs

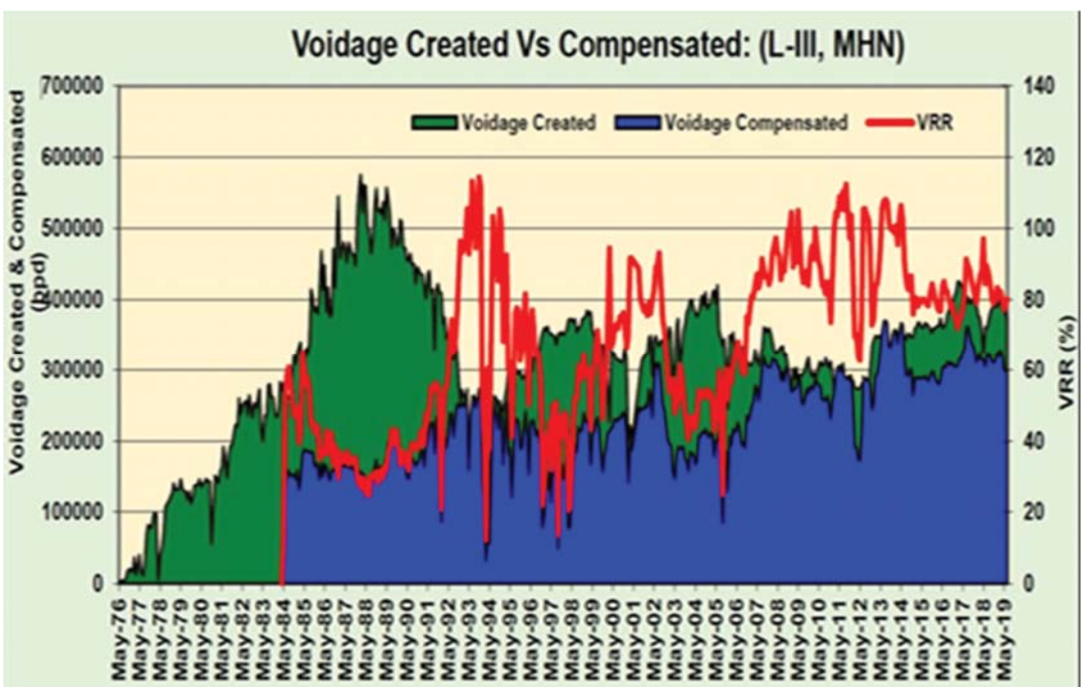
					2014-15			
Sl. No.	**Particulars**	**Planned**			**Actual**			**Shortfall -MH**
		MHN	**MHS**	**MH**	**MHN**	**MHS**	**MH**	
1	New water injector drilling strings	2	0	2	0	0	0	2
2	Workover jobs (WOJ)//Side track (ST) in existing water injectors strings	14	5	19	4	3	7	12
3	Rig less water injector conversion strings	6	7	13	5	6	11	2
4	Resumption of water injection strings	7	33	40	5	28	33	7
5	Stimulation strings	10	24	34	9	11	20	14
					2015-16			
Sl. No.	**Particulars**	**Planned**			**Actual**			**Shortfall-MH**
		MHN	**MHS**	**MH**	**MHN**	**MHS**	**MH**	
1	New water injector drilling strings	2	0	2	0	0	0	2
2	Rig less water injector conversion strings	3	3	6	0	0	0	6
3	Choke size increase strings	1	0	1	1	0	1	0
4	WOJ/ST in existing water injectors	30	30	60	7	8	15	45
5	MIP for additional injection	1	3	4	0	2	2	2
6	Resumption of water injection strings	9	0	9	3	1	4	5
7	Stimulation	16	34	50	12	23	35	15
8	Strings for PFA replacement	0	9	9	0	4	4	5
					2016-17			
Sl. No.	**Particulars**	**Planned**			**Actual**			**Shortfall-MH**
		MHN	**MHS**	**MH**	**MHN**	**MHS**	**MH**	
1	New water injector drilling	2	0	2	0	0	0	2
2	Rig less water injector conversion	0	2	2	0	0	0	2
3	WI conversion after Work over/ side track	2	0	2	0	0	0	2
4	WOJ/ST in existing water injectors	3	6	9	2	1	3	6
5	Choke size increase	3	0	3	2	0	2	1
6	Resumption of water injection	11	8	19	10	8	18	1
7	Stimulation	9	28	37	6	10	16	21
					2017-18			
Sl. No.	**Particulars**	**Planned**			**Actual**			**Shortfall-MH**
		MHN	**MHS**	**MH**	**MHN**	**MHS**	**MH**	
1	New water injector drilling	2	0	2	3	0	3	-1
2	Rig less water injector conversion	8	4	12	5	0	5	7
3	WI conversion after Work over/ side track	7	4	11	1	0	1	10
4	WOJ/ST in existing water injectors	9	11	20	3	7	10	10
5	Profile modification jobs	3	0	3	0	0	0	3
6	Resumption of water injection	2	7	9	2	7	9	0
7	Stimulation	18	18	36	5	23	28	8
					2018-19			

Sl. No.	Particulars	Planned			Actual			Shortfall-MH
		MHN	MHS	MH	MHN	MHS	MH	
1	New water injector drilling	3	0	3	1	0	1	2
2	Rig less water injector conversion	4	5	9	3	5	8	1
3	WI conversion after workover/ side track	6	6	12	0	1	1	11
4	WOJ/ST in existing water injectors	6	5	11	1	2	3	8
5	Profile modification jobs	4	0	4	2	0	2	2
6	Resumption of water injection	9	17	26	10	38	48	-22
MHN - Mumbai High North, MHS - Mumbai High South, MH - Mumbai High								

Annexure-IV
(as referred to in Para 3.6)
Mumbai High South

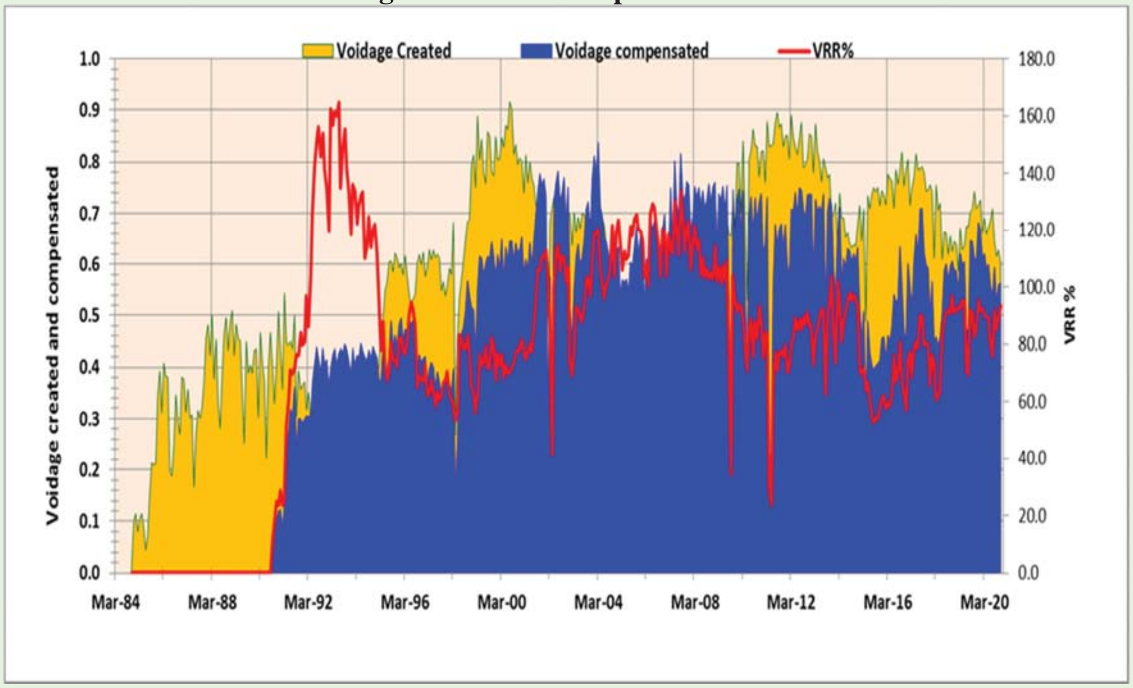


Mumbai High North

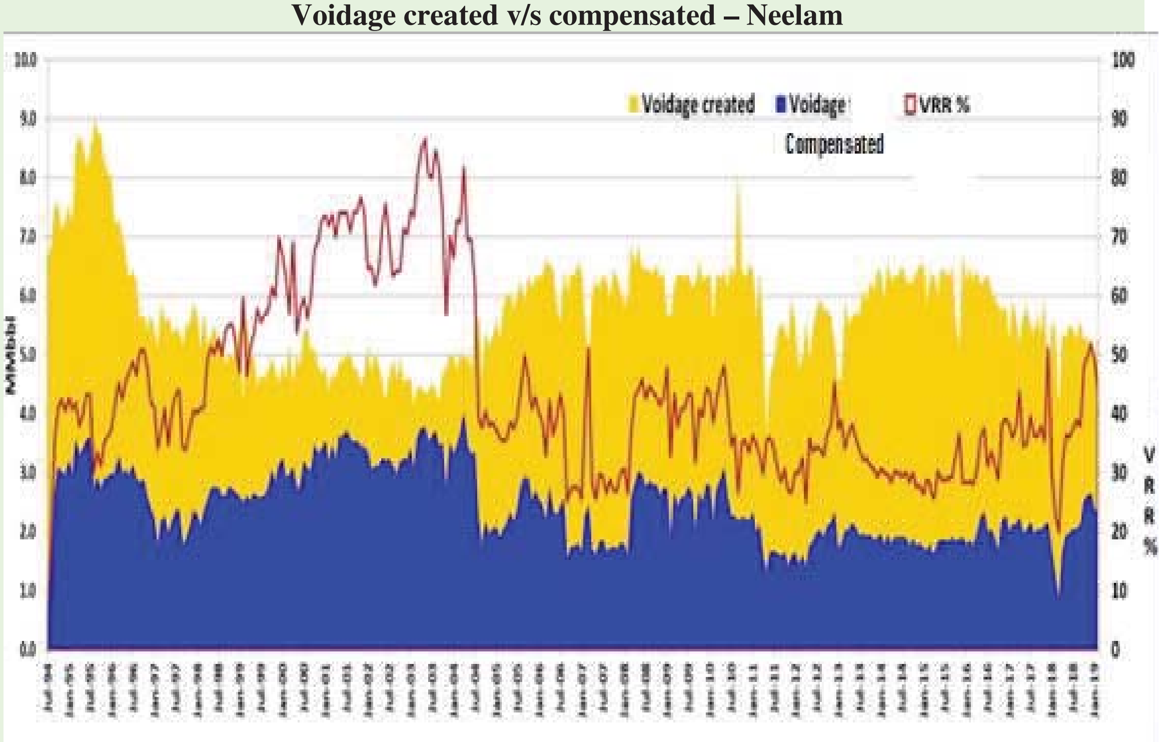


VRR - Voidage Replacement Ratio

Voidage created v/s compensated - Heera



Voidage created v/s compensated – Neelam



VRR - Voidage Replacement Ratio

Annexure V
(as referred in Para 4.2)
Major Water Injection equipment

Platform	Major equipment installed	Installed quantity	Standby philosophy
Mumbai South			
Water Injection South (WIS)	Sea Water Lift Pump	3	2R +1SB
	Booster Pump	3	2R+1SB
	Main Injection Pump	5	4R+1SB
	Fine Filter	12	10R+1SB+1BW
	DO Tower	2	2R
	Vacuum Pump	4	2R+2SB
	Chlorinator	2	1R+1SB
Infill Complex Water Injection (ICW)	Sea Water Lift Pump	3	2R+1SB
	Booster Pump	3	2R+1SB
	Main Injection Pump	5	4R+1SB
	Fine Filter	6	4R+1SB+1BW
	DO Tower	2	2R
	Vacuum Pump	4	2R+2SB
	Chlorinator	2	1R+1SB
South High Water Injection (SHW)	Sea Water Lift Pump	3	2R+1SB
	Booster Pump	3	2R+1SB
	Main Injection Pump	5	4R+1SB
	Fine Filter	7	6R+1SB
	DO Tower	2	2R
	Vacuum Pump	4	2R+2SB
	Chlorinator	2	1R+1SB
Mumbai High North			
Mumbai North Water Injection (MNW)	Sea Water Lift Pump	3	2R+1SB
	Booster Pump	3	2R+1SB
	Main Injection Pump	5	4R+1SB
	Fine Filter	5	4R+1SB
	DO Tower	2	1R+1SB
	Vacuum Pump	4	2R+2SB
	Chlorinator	2	1R+1SB
Water Injection North (WIN)	Sea Water Lift Pump	3	2R+1SB
	Booster Pump	3	2R+1SB
	Main Injection Pump	5	4R+1SB
	Fine Filter	8	6R+1SB+1BW

Platform	Major equipment installed	Installed quantity	Standby philosophy
	DO Tower	2	2R
Heera			
Heera Water Injector	Sea Water Lift Pump	3	2R+1SB
	Booster Pump	3	2R+1SB
	Main Injection Pump	5	3R+2SB
	Fine Filter	6	4R+2SB
	DO Tower	1	1R+0SB
	Vacuum Pump	2	1R+1SB
	Chlorinator	1	1R+0SB
Neelam			
Neelam water Injection (NLW)	Sea Water Lift Pump	3	2R+1SB
	Booster Pump	3	2R+1SB
	Main Injection Pump	4	2R+2SB
	Fine Filter	6	4R+2SB
	DO Tower	2	1R+1SB
	Vacuum Pump	4	2R+2SB
	Chlorinator	1	1R+0SB
Note: R-Running, SB-Standby, BW-Backwash			

Annexure-VI
(as referred to in para 4.4)
Replacement life of water injection equipment

Equipment	Replacement life (whichever is earlier)
Main Injection Pump	20 years or 1,50,000 hours
Sea Water Lift pump	15 years or 1,10,000 hours
Booster Pump	Not furnished to Audit
Chlorinator	15 years
Dosing Pump	10 years
Other small pump	10 years
LT motors (<25 KW)	10 years
LT motors (>25 KW)	15 years
Vacuum pump-DO tower	Condition based**
Vacuum pump motor-DO tower	Condition based**
Fine Filters/coarse filters	Condition based**

***** This equipment are not falling into specific provisions of the policy and therefore, its replacement is decided on the basis of specific condition/performance/repair economics.***

Annexure-VII
(as referred to in para 4.5)
System availability of water injection

Infill Complex Water Injection Platform								
Year	SWLP	BP	MIP	VP	DO Tower	Fine Filters	Coarse Filters	Chlorinators
2014-15	100	99.1	94	100	77.6	88.5	0	22.54
2015-16	100	99.9	72.3	100	84.3	91.0	0	47.77
2016-17	98.8	100	82.2	98.1	99.4	94.2	0	46.02
2017-18	100	100	97.9	100	97	98.0	0	0
2018-19	100	100	100	98.7	98.5	99.5	0	0
Mumbai North Water Injection Platform								
Year	**SWLP**	**BP**	**MIP**	**VP**	**DO Tower**	**Fine Filters**	**Coarse Filters**	**Chlorinators**
2014-15	100	100	100	100	100	100	0	100
2015-16	100	100	100	100	100	100	0	100
2016-17	100	100	100	100	100	100	0	100
2017-18	100	100	100	100	100	100	0	100
2018-19	99.8	100	100	100	100	100	0	100
South High Water Injection Platform								
Year	**SWLP**	**BP**	**MIP**	**VP**	**DO Tower**	**Fine Filters**	**Coarse Filters**	**Chlorinators**
2014-15	100	98.9	98	99.1	100	100	0	0
2015-16	99.8	100	99.9	83.7	100	100	0	0
2016-17	99.5	98.7	99.6	98.8	100	100	0	0
2017-18	98.9	97.4	97.4	74.2	100	100	0	0
2018-19	87.3	92.9	85.5	75.9	100	93.5	0	0
Water Injection North Platform								
Year	**SWLP**	**BP**	**MIP**	**VP**	**DO Tower**	**Fine Filters**	**Coarse Filters**	**Chlorinators**
2014-15	100	100	100	100	100	100	0	100
2015-16	100	100	100	100	100	100	0	99.58
2016-17	100	100	100	87	100	100	0	100
2017-18	100	100	100	100	100	87.5	0	100
2018-19	100	100	100	100	100	84.4	0	98.97
Water Injection South Platform								
Year	**SWLP**	**BP**	**MIP**	**VP**	**DO Tower**	**Fine Filters**	**Coarse Filters**	**Chlorinators**
2014-15	100	98.7	99.5	48.8	100	63.1	0	0
2015-16	100	99.8	99.9	14.3	100	58.2	0	0
2016-17	100	91.0	99.1	65.2	99.6	58.2	0	0
2017-18	100	85.0	100.0	66.1	99.9	62.4	0	0
2018-19	100	49.3	100.0	50.0	69.7	64.9	0	0
Water Injection Heera Platform								
Year	**SWLP**	**BP**	**MIP**	**VP**	**DO Tower**	**Fine Filters**	**Coarse Filters**	**Chlorinators**
2014-15	100	100	100	100	99.8	100	0	0

2015-16	100	100	100	100	99.8	100	0	0
2016-17	100	100	100	100	99.7	100	0	0
2017-18	100	100	100	100	99.5	100	0	0
2018-19	100	100	100	100	99.6	100	16	0
Neelam Water Injection Platform								
Year	**SWLP**	**BP**	**MIP**	**VP**	**DO Tower**	**Fine Filters**	**Coarse Filters**	**Chlorinators**
2014-15	99.40	100.00	99.00	99	100	100	0	0
2015-16	99.89	100.00	99.46	99	100	100	0	0
2016-17	100.00	100.00	100.00	99	100	100	0	0
2017-18	99.30	100.00	86.68	99	100	100	0	0
2018-19	99.60	100.00	93.76	99	100	100	0	0

Source: Management response of Mumbai high and Neelam Heera regarding Equipment availability and System availability.
SWLP - Sea Water Lift Pump, BP - Booster Pump, MIP - Main Injection Pump, VP - Vacuum Pump , DO Tower - De-oxygenation Tower

Annexure-VIII
(as referred to in Para 4.6)

Instances of running hours/ despatch data in Monthly reports during repair

Month/ Year	Running hrs	Standby hrs	Maintenance/ Downtime hrs	Availability (%)	Main Injection Pump (MIP) 6680 at repairs - April 2014 to March 2018
May 2014	24	0	720	3.2	
July 2014	24	0	720	3.2	
August 2014	24	0	720	3.2	

Running hour (MIP) shown nil but water despatch reported

Month/ Year	Main Injection Pump (MIP)	Running hrs.	Standby Hrs.	Maintenance/ Downtime Hrs.	Availability (%) (monthly)	MIP despatch data reported in the Monthly reports
October 2015	MIP 1	0	742	2	99.7	295732
	MIP 2	0	742	2	99.7	
	MIP 3	0	0	744	0.00	
	MIP 4	0	0	744	0.00	

Booster Pump (TAG No. 6620) - running hour depicted same as maintenance/ downtime hour

Month/ Year	Running hrs.	Standby hrs.	Maintenance/ Downtime Hrs.	Availability (percentage)
December 2016	666	78	666	10.5
January 2017	711	33	711	4.4
February 2017	558	114	558	17.0
March 2017	537	205	539	27.6
April 2017	655	63	657	8.8
May 2017	663	79	665	10.6
June 2017	675	43	677	6.0
July 2017	219	523	221	70.3
August 2017	219	523	221	70.3

Annexure-IX
(as referred to in Para 5.3)
Average quality of injection water

MUMBAI HIGH ASSET						
WIS Platform						
Parameter	**Limit**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**
TSS (Mg/Lt)	<0.2	0.212	0.242	0.2632	0.27	0.287
Millipore (Lt/30 minutes)	>6	10.159	9.133	Particle analyser (PA) not working	7.5	7.8
Turbidity (NTU)	<0.2	0.213	0.176	Turbidity meter not working	0.25	0.231
Particle count No./ml	<2000	PA not working			845	1104
Dissolved Oxygen (ppb)	<20	491.65	2251.083	2059.8	3565	2858
Residual Sulphite (Mg/lt)	>1.0	0.981	0.767	0.542	0.21	Nil
Iron Count (No/ml)	<0.05	0.092	0.060	0.07275	0.080	0.089
Sulphide (Mg/lt)	Nil	Nil	Nil	Nil	Nil	Nil
ICW Platform						
Parameter	**Limit**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**
TSS (Mg/Lt)	<0.2	0.180	0.166	0.177	0.211	0.17
Millipore(Lt/30 minutes	>6	9.183	10.80	9.55	7.3	7.1
Turbidity (NTU)	<0.2	0.183	0.157	0.1825	0.21	0.177
Particle count No./ml	<2000	PA not working				
Dissolved Oxygen (ppb)	<20	93.96	206.33	497	415	Nil
Residual Sulphite (Mg/lt)	>1.0	0.474	0.660	0.60	0.51	0.44
Iron Count (No/ml)	<0.05	0.048	0.052	0.049	0.062	0.053
Sulphide (Mg/lt)	Nil	Nil	Nil	Nil	Nil	Nil
SHW Platform						
Parameter	**Limit**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**
TSS (Mg/Lt)	<0.2	0.165	0.175	0.22	Sampling point not available	
Millipore(Lt/30 minutes	>6	11.11	9.244	7.78	Sampling point not available	
Turbidity (NTU)	<0.2	0.205	0.217	0.235	0.31	0.33
Particle count No./ml	<2000	771.85	1444.583	2200	3246	3875
Dissolved Oxygen (ppb)	<20	1253.43	1367.583	2029.8	2050	1237
Residual Sulphite (Mg/lt)	>1.0	0.752	0.531	0.70	0.80	0.29
Iron Count (No/ml)	<0.05	0.081	0.113	0.212	0.235	0.22
Sulphide (Mg/lt)	Nil	Nil	Nil	Nil	Nil	Nil
MNW Platform						
Parameter	**Limit**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**
TSS (Mg/Lt)	<0.2	0.194	0.201	0.19	0.188	0.190
Millipore(Lt/30 minutes	>6	8.909	8.641	9.52	8.3	8.2
Turbidity (NTU)	<0.2	0.223	0.197	0.19	0.19	0.18
Particle count No./ml	<2000	1310.49	**PA not working**		774	1234
Dissolved Oxygen (ppb)	<20	62.31	75.167	45.33	52	Nil
Residual Sulphite (Mg/lt)	>1.0	0.886	1.057	0.75	0.57	0.69
Iron Count (No/ml)	<0.05	0.059	0.048	0.050	0.061	0.057
Sulphide (Mg/lt)	Nil	Nil	Nil	Nil	Nil	Nil
WIN Platform						
Parameter	**Limit**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**
TSS (Mg/Lt)	<0.2	0.87	0.415	0.33	0.32	0.244
Millipore(Lt/30 minutes	>6	8.26	8.058	7.34	8	8.2
Turbidity (NTU)	<0.2	0.38	0.32	0.31	0.3	0.24
Particle count No./ml	<2000	2132	PA not working	2313	2213	PA not working
Dissolved Oxygen (ppb)	<20	244	104	85	165	Nil
Residual Sulphite (Mg/lt)	>1.0	1.04	1.063	1.05	1.05	0.717
Iron Count (No/ml)	<0.05	0.04	0.047	0.048	0.045	0.049
Sulphide (Mg/lt)	Nil	Nil	Nil	Nil	Nil	Nil

Neelam Field

Parameter	Limit	2014-15	2015-16	2016-17	2017-18	2018-19
TSS (Mg/Lt)	<0.20	0.36	0.26	0.29	0.26	0.27
Millipore(Lt/ 30 minutes	5-7 MIN	4.70	6.55	6.08	5.85	5.42
Turbidity (NTU)	<0.20	0.35	0.23	0.26	0.25	0.29
Particle count No./ml	<2000	2545.83	1084.58	1285.92	2344.00	1266.01
Dissolved Oxygen (ppb)	<20	16.92	20.87	10.27	65.74	37.75
Residual Sulphite (Mg/lt)	1.0 MIN	1.00	0.87	1.00	1.02	0.81
Iron Count (No/ml)	<0.05	0.31	0.20	0.15	0.04	0.25
Sulphide (Mg/lt)	NIL	Nil	Nil	Nil	Nil	Nil

Heera field

Parameter	Limit	2014-15	2015-16	2016-17	2017-18	2018-19
TSS (Mg/Lt)	<0.20	0.18	0.19	0.20	0.32	0.78
Millipore(Lt/ 30 minutes	5-7 MIN	7.82	7.79	7.29	5.49	3.82
Turbidity (NTU)	<0.20	0.12	0.13	0.19	0.30	0.31
Particle count No./ml	<2000	991.00	1144.92	1859.17	1391.17	2499.84
Dissolved Oxygen (ppb)	<20	38.47	55.39	23.28	52.01	202.23
Residual Sulphite (Mg/lt)	1.0 MIN	1.17	1.15	1.26	0.81	0.92
Iron Count (No/ml)	<0.05	0.04	0.04	0.04	0.17	0.07
Sulphide (Mg/lt)	NIL	Nil	Nil	Nil	Nil	Nil

Source: Mumbai high, Neelam Heera Chemistry Monthly Reports

Annexure-X
(as referred to in Para 5.5)
Lower dosing of water injection chemicals against recommended norms

Coagulant							
Year	**Dosing norm-ppm**	**WIN**	**WIS**	**ICW**	**SHW**	**MNW**	**Average**
2014-15	0.4 to 0.8	0.19	0	0	0.2	0.2	0.12
2015-16		0.43	0	0.26	0	0.37	0.21
2016-17		0.15	0	0.01	0	0.18	0.07
2017-18		0.18	0	0.41	0	0.29	0.18
2018-19		0.26	0	0.37	0	0.44	0.21

Poly Aluminium Chloride (PAC)							
Year	**Dosing norm-ppm**	**WIN**	**WIS**	**ICW**	**SHW**	**MNW**	**Average**
2014-15	0.4 to 0.8	0.4	0.64	0.41	0.21	0.42	0.42
2015-16		0.62	0.53	0.35	0.23	0.47	0.44
2016-17		0.88	0.82	0.45	0.13	0.44	0.55
2017-18		0.55	1.59	0.14	0	0.21	0.50
2018-19		0.73	1.12	0.7	0	0.22	0.55

Oxygen scavenger							
Year	**Dosing norm-ppm**	**WIN**	**WIS**	**ICW**	**SHW**	**MNW**	**Average**
2014-15	10	5.25	6.94	7.35	5.6	8.41	6.71
2015-16		7.07	8.7	6.75	5.83	8.58	7.39
2016-17		8.12	7.46	7.96	5.17	5.32	6.81
2017-18		7.14	5.2	7.92	4.93	5.95	6.23
2018-19		7.61	11.15	10.13	8.87	7.46	9.04

Water Corrosion Inhibitor							
Year	**Dosing norm- ppm**	**WIN**	**WIS**	**ICW**	**SHW**	**MNW**	**Average**
2014-15	20	5.81	7.33	8.67	4.83	7.59	6.85
2015-16		7.27	8.31	8.81	5.56	8.63	7.72
2016-17		8.75	6.65	11.03	3.58	5.56	7.11
2017-18		2.78	5.33	6.08	2.12	2.79	3.82
2018-19		8.02	10.75	9.82	6.24	9.99	8.96

Annexure-XI
(as referred to in Para 5.6)
Recommendations on measurement of water quality at wellhead

Sl. No.	Institute study report	Observations	Recommendations
1.	IRS Manual on Offshore Injection Water Quality - March 1994	Emphasis of monitoring needs to be laid at the well heads rather than at the process platforms. But, unfortunately, reverse is the case at Mumbai High, where energy as well as manpower is utilised at the process platforms and monitoring at the wellheads is being neglected. In the process, wellheads are not being regularly monitored in a planned way, and thus operational engineer is unaware of the quality of the water injected inside the reservoir. Irregular monitoring carried out at wellheads indicate that the injection water quality is bad and not as per specifications. But, it seems that, this fact has not been taken up seriously and no remedial measures have been undertaken to improve the injection water quality so as to bring it back within operational limits.	Weekly monitoring of all water quality parameters at all wellhead
2.	IRS study report on Injection water quality and injectivity assessment of injectors in Mumbai High - March 2011	Deterioration in water quality parameters in injection lines during transportation from fine filters to wellhead. In most of the back wash samples, total suspended solids (TSS) and turbidity was quite high and filterability was quite low than the desired value. Reduction in sulphate irons and increase in iron content indicates sulphate reducing bacteria (SRB) activity. Reduction in calcium, magnesium, bicarbonate indicate tendency for scaling.	Regular monitoring of water quality after fine filter, injector header and wellhead is needed.
3.	In-house committee report on Facility cost optimisation and water injection improvement in Mumbai High - July 2012	Analysis of pigging flushing water and backflow water analysis revealed that deterioration in water quality parameters in injection lines during transportation from fine filters to well head. In most of the back wash samples, high total suspended solids and turbidity and low filterability observed. SRB and scaling activity due to reduction in sulphate irons and increase in iron content, reduction in calcium, magnesium, bicarbonate.	Regular monitoring of water quality after fine filters, injection header and wellhead.
4.	IOGPT report on Premature failure of water injection lines - August 2014	In Mumbai High North, impairment in injectivity due to tubing leakage/ casing damage mainly due to corrosion which has taken place over the years because of poor injection water quality and Mumbai High South poor injectivity in the wells on account of impairment/ chocking of formation due to foreign material reaching into the formation along with injected water. Non availability of desired chemical affect the maintaining water quality	Regular monitoring of water injection quality at unmanned platforms including presence of oxygen, particle counts, Millipore test, residual sulphite, corrosion rate and SRB count on monthly basis.

Annexure XII
Deterioration in water quality on the way to wellhead (as referred in Para 5.6)

Sl. No.	Water quality measured at process complex				Water quality measured at Unmanned platform				Deterioration in water quality from WI platform to wellhead (in number of times)	
	Process platform	Date of sampling	Iron content (mg/lt)	Turbidity (NTU)	Well Head	Date of sampling	Iron content (mg/lt)	Turbidity (NTU)	Iron content (mg/lt)	Turbidity (NTU)
1	BHS	10.11.18	0.088	*	SB-1	10.11.18	2.8	*	31.8	*
2	BHS	10.11.18	0.088	*	SB-2	10.11.18	1.6	*	18.2	*
3	MHN	04.06.16	0.04	0.19	N11	04.06.16	2.1	1.76	52.5	9.26
4	MHN	09.07.16	0.059	0.19	N11	09.07.16	0.9	2.4	15.3	12.63
5	MHN	02.05.16	0.04	0.17	N15	02.05.16	1	1.2	25.0	7.06
6	MHN	29.05.16	0.04	0.18	N15	29.05.16	3	1.06	75.0	5.89
7	MHN	14.06.16	0.04	0.21	N15	14.06.16	1.5	1.08	37.5	5.14
8	MHN	05.07.16	0.054	0.19	N16	05.07.16	1.2	0.63	22.2	3.32
9	MHN	21.05.16	0.04	0.17	NB	21.05.16	0.6	1.1	15.0	6.47
10	MHN	10.06.16	0.04	0.19	NB	10.06.16	1.2	0.6	30.0	3.16
11	MHN	11.07.16	0.058	0.2	NB	11.07.16	1.2	0.94	20.7	4.70
12	MHN	05.05.16	0.04	0.17	NS	05.05.16	0.9	1.3	22.5	7.65
13	MHN	09.07.16	0.059	0.19	NS	09.07.16	0.6	1.22	10.2	6.42
14	MHN	19.05.16	0.04	0.16	NW	19.05.16	0.9	3.87	22.5	24.19
15	MHN	10.09.18	0.069	0.19	NS	10.09.18	>1.0	8.3	*	43.68
16	MHN	10.09.18	0.069	0.19	WA	10.09.18	>1.0	13	*	68.42
17	MHN	25.11.18	0.047	0.2	N5	25.11.18	<1.0	4.7	*	23.50
18	MHN	05.05.16	0.04	0.17	WA	05.05.16	2.4	4.1	60.0	24.12
19	MHN	10.09.18	0.069	0.19	WA	10.09.18	>1.0	13	*	68.42
20	MHN	05.05.16	0.04	0.17	WA	05.05.16	2.4	4.1	60.0	24.12
21	MHN	20.05.16	0.04	0.18	WI4	20.05.16	0.3	0.14	7.5	0.78
22	MHN	11.07.16	0.058	0.2	WI4	11.07.16	0.6	0.99	10.03	4.95
23	MHN	01.06.16	0.04	0.16	WI6	01.06.16	0.6	2.55	15.0	15.94
24	MHN	09.09.18	0.069	0.19	N11	09.09.18	>1.0	2.83	*	14.89
25	MHN	29.05.16	0.04	0.18	N15	29.05.16	3	1.06	75.0	5.89
26	MHN	01.08.16	0.06	0.23	N15	01.08.16	1.2	1.1	20.0	4.78
27	MHN	21.08.16	0.047	0.18	N15	21.08.16	0.9	0.94	19.1	5.22
28	MHN	07.09.18	0.07	0.18	N15	07.09.18	>1.0	11.7	*	65.00
29	MHN	10.09.18	0.069	0.19	N19	10.09.18	>1.0	2.4	*	12.63
30	MHN	29.11.18	0.46	0.18	N19	29.11.18	<1.0	7.44	*	41.33
31	MHN	28.11.18	0.047	0.19	RS5	28.11.18	<1.0	5.45	*	28.68
32	MHN	28.11.18	0.047	0.19	RS5	28.11.18	<1.0	5.45	*	28.68
33	MHN	28.11.18	0.047	0.19	NV	28.11.18	<1.0	2.87	*	15.11
34	MHN	04.12.18	0.048	0.18	NV	04.12.18	<1.0	2.87	*	15.94
35	MHN	22.01.19	0.047	0.18	ZC	22.01.19	<1.0	28	*	155.56
36	MHN	22.02.19	0.049	0.18	ZC	22.02.19	<1.0	28	*	155.56
37	WIN	13.12.17	0.048	0.37	W13-3	13.12.17	1.8	2.88	37.5	7.78
38	WIN	13.12.17	0.048	0.37	W13-3	13.12.17	1.7	2.75	35.4	7.43
39	WIN	13.12.17	0.048	0.37	W13-3	13.12.17	1.7	2.29	35.4	6.19
40	WIN	28.03.18	0.043	0.22	W12	28.03.18	1.4	*	32.6	*
								Average	**30.24**	**25.42**

Source: Monthly Performance Reports of Chemistry section

**** Data not available***

Annexure XIII
(as referred to in Para 7.1)

Gist of observations and recommendations of consultants/ internal committees of the company on reservoir health

(i) **Bombay High Review Committee** headed by Shri A.B. Das Gupta was appointed (April 1990) by the Ministry of Petroleum & Natural Gas to find answers related to various issues including pressure maintenance facilities. The Report stated (November 1990) that greater voidage was caused by the excess gas production from wells with high Gas Oil Ratio and delayed implementation of water injection. If gas was coming from LIII reservoir (major producing reservoir) it could be ending up with lower recoveries than would be feasible through a more stringent control of GOR. The reservoir could not be expected to give the predicted ultimate recoveries unless GOR was kept within the cut-off point.

(ii) **M/s. Ganesh Thakur**, an international consultant was engaged (2007) by the company to address the low-pressure areas and to improve voidage compensation/ reservoir health and sweep efficiency. The project report recommended for accelerated water injection, injection build up for achieving 100 *per cent* voidage replacement, and stimulation of low Injectivity wells in Mumbai High field. In Heera, it was observed that with increased water injection, once the pressure increases to about 1500 psi from the then levels of 1200 psi, the oil rate was estimated to increase.

(iii) **M/s William Cobbs and Associates,** an international consultant appointed (August 2009) by the Company to conduct a workshop on water injection stated that the cumulative voidage replacement ratio, since start of injection was less than one and as a result, reservoir pressure continued to decline in the field resulting in decline in well productivity. For effective voidage replacement, the consultant suggested to keep VRR values greater than 100 *per cent* (usually 110 to 130 *per cent*).

(iv) **In-house taskforce** constituted by Mumbai High for Augmentation and Redistribution of water injection in Mumbai High field stated (October 2018) that uneven distribution of water injection has led to the differential depletion in the reservoir laterally and within layers, resulting localised pressure sinks and/ or high-water production in different parts of the reservoir. Taskforce emphasised for effectiveness of water injection for pressure maintenance and improving sweep by targeting Incremental voidage compensation levels of 100 to 120 *per cent* and re-distributing injection water.

(v) **M/s. Gaffney, Cline & Associates (GCA)** was appointed by the company to perform an independent review of ONGC production profile for Mumbai High field. In its report (December 2019), GCA concluded that disruption and/ or delay in water injection contributed to higher decline in production, through reduced well productivity and declining reservoir pressure. It recommended improving sweep efficiency and restoring reservoir energy, focusing on injection plan and increasing voidage replacement ratio and maintaining voidage replacement above 100 *per cent*. GCA opined that Management production profile could be achieved only if water injection is maintained at high level of efficiency and recommended to maintain integrity of injection network.

(vi) **M/s. GCA** was also appointed to perform independent review of production profile of Heera field. In its report, M/s.GCA stated (December 2019) that the profile is valid only if water injection is maintained as per the HRP III redevelopment scheme. Historically, water injection was not stable due to several reasons including injection shutdowns and that pressure sinks had developed in some parts of Heera. Reduction in water injection by 21 *per cent* during 2012-19, had resulted in liquid rates dropping by 21 *per cent*. GCA recommended ONGC to conduct an extensive pressure surveillance programme as the available pressure data was sparse and incoherent.

Annexure-XIV A
(as referred to in Para 7.3)

Statement indicating value of deficit due to insufficient water injection in Mumbai High field

Mumbai High Field Year	ONGC working			Audit working								
	FR recommended simulation model with 6% losses (MMT)	**FR recommended with actual WI-simulation model with 6% losses (MMT)****	**Oil short-fall (MMT)**	**Oil shortfall without 6% losses (MMT)**	**Actual losses (%)**	**Oil short-fall (MMT)**	**PPAC crude oil rate per bbl (US$)**	**Exchange Rate US$=₹**	**Value of oil deficit (₹ in crore)**	**ONGC Realised crude oil rate per bbl net of subsidies & levies**	**ONGC realisation value less of subsidy and statutory levies (₹ in crore)**	**Loss of revenue to Govt. (₹ in crore)**
	(a)	(b)	(c)= (a)-(b)	(d)= (c)*100/94	(e)	(f)= (d)-(d*e/100)	(g)	(h)	(i)=(f)*(g)*(h)*7.6 $*10^6/10^7$	(j)	(k)	(l)= (i)-(k)
2014-15	9.018	8.873	0.145	0.154	0.64	0.153	84.156	61.15	599.44	36.35	258.92	340.52
2015-16	8.995	8.625	0.371	0.395	0.64	0.392	46.166	65.46	900.71	32.71	636.42	264.29
2016-17	8.84	8.323	0.517	0.550	1.55	0.541	47.558	67.09	1,312.98	35.88	990.69	322.29
2017-18	8.567	7.971	0.596	0.634	2.35	0.619	56.427	64.18	1,704.10	40.44	1226.44	477.66
2018-19	8.056	7.39	0.666	0.709	1.96	0.695	69.880	69.90	2,578.78	50.77	1873.35	705.43
Total	**43.476**	**41.182**	**2.295**	**2.441**		**2.401**			**7,096.01**		**4985.82**	**2110.19**

*****The production as per simulation model has been reworked by the Management after changing only the water injection quantity as per actual.***

Annexure-XIV B
(as referred to in para 7.3)
Statement indicating value of deficit due to insufficient water injection in Neelam & Heera fields

Heera Field Year	ONGC working			Audit working								
	FR recommended simulation model with 6% losses MMT	FR recommended with actual WI-simulation model with 6% losses MMT**	Oil Shortfall MMT	Oil Shortfall without 6% losses MMT	Actual losses (%)	Oil Short-fall MMT	PPAC crude oil rate per bbl US$	Exchange Rate US$=₹	Value of oil deficit (₹ in crore)	ONGC Realised crude oil rate per bbl net of subsidies & levies	ONGC realisation value less of subsidy and statutory levies (₹ in crore)	Loss of revenue to Govt. (₹ in crore)
	(a)	(b)	(c)= (a)-(b)	(d)= (c)*100/94	(e)	(f) = (d) - (d*e/100)	(g)	(h)	(i)=(f)*(g)*(h)*7.6*$10^6/10^7$	(j)	(k)	(l)= (i)-(k)
2014-15	2.174	1.979	0.195	0.207	6.44	0.194	84.156	61.1471	759.05	36.35	327.88	431.17
2015-16	2.223	1.982	0.241	0.256	0.00	0.256	46.166	65.4611	588.85	32.71	417.20	171.65
2016-17	2.199	1.949	0.25	0.266	3.55	0.257	47.558	67.0896	622.02	35.88	469.33	152.70
2017-18	2.117	1.844	0.273	0.290	10.16	0.261	56.427	64.1781	718.11	40.44	516.84	201.27
2018-19	1.979	1.638	0.341	0.363	11.22	0.322	69.88	69.901	1195.62	50.77	868.58	327.03
Total	**10.692**	**9.392**	**1.3**	**1.383**		**1.290**			**3883.66**		**2599.84**	**1283.82**

Neelam Field Year	ONGC working			Audit working								
	FR recommended simulation model with 6% MMT	FR recommended with actual WI-simulation model with 6% losses MMT**	Oil Short-fall MMT	Oil Shortfall without 6% losses MMT	Actual losses (%)	Oil Short-fall MMT	PPAC crude oil rate per bbl US$	Exchange Rate US$=₹	Value of oil deficit (₹ in crore)	ONGC Realised crude oil rate per bbl net of subsidies & levies	ONGC realisation value less of subsidy and statutory levies (₹ in crore)	Loss of revenue to Govt. (₹ in crore)
	(a)	(b)	(c)= (a)-(b)	(d)= (c)*100/94	(e)	(f)= (d)-(d*e/100)	(g)	(h)	(i)=(f)*(g)*(h)*7.6*$10^6/10^7$	(j)	(k)	(l)= (i)-(k)
2015-16	0.763	0.755	0.008	0.009	3.06	0.008	46.166	65.4611	18.95	32.71	13.43	5.52
2016-17	0.701	0.675	0.026	0.028	3.52	0.027	47.558	67.0896	64.71	35.88	48.83	15.89
2017-18	0.639	0.61	0.029	0.031	16	0.026	56.427	64.1781	71.32	40.44	51.33	19.99
2018-19	0.710	0.674	0.036	0.038	0.03	0.038	69.88	69.901	142.13	50.77	103.26	38.88
Total	**2.813**	**2.714**	**0.099**	**0.105**		**0.099**			**297.12**		**216.84**	**80.28**
NH Total						**1.389**			**4180.77**		**2816.68**	**1364.10**

***** The production as per simulation model has been reworked by the Management after changing only the water injection quantity as per the actual.***